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Date: December 4, 1998

Subject: Review of 1998 Douglas-fir Beetle Infestations on the Pine Ranger District and Hells Canyon National Recreation Area (Report No. BMZ-99-1)

To: Forest Supervisor, Deputy Forest Supervisor, and District Rangers, Wallowa-Whitman NF

This letter transmits my report (Report No. BMZ-99-1) on two trips I made to the north end of the Wallowa-Whitman NF this summer to review insect infestations in stands on the Pine Ranger District and Hells Canyon National Recreation Area (HCNRA). Information in this report is pertinent to most districts on the Wallowa-Whitman since the conditions described in this report, with respect to Douglas-fir beetle, occur on many districts based on 1998 aerial insect detection survey results that have recently become available to the districts (i.e. 1998 insect survey maps from the RO).

On July 22, 1998 I visited the Pine Ranger District at the request of Joe Sciarrino, District Silviculturist. The purpose of my visit was to review new infestations of Douglas-fir beetle (*Dendroctonus pseudotsugae*) that had been observed in several drainages on the east side of the Pine District this summer by district personnel. On July 28, 1998 I visited the Hells Canyon National Recreation Area at the request of Paul Survis, District Silviculturist. This visit to the HCNRA initially was requested to investigate the status of populations of Douglas-fir tussock moth (*Orgyia pseudotsugata*) in stands of the Imnaha River drainage, which we found to be low. However, after entering the Imnaha River canyon, we soon discovered widely-scattered populations of Douglas-fir beetle in both sides of the drainage, and in other nearby subdrainages adjacent to Forest Road 39, including Lonesome Saddle area, Lonesome Creek, Duck Creek, the northern headwaters of Pine Creek, Dutchman Creek, and North Creek, among others. Subsequent reconnaissance of the districts, and review of the recent insect survey maps have determined that Douglas-fir beetle infestations are widespread on the Forest, and have increased from recent years. Similar conditions are presently occurring on the Boise and Payette NFs, in northern Idaho, and in other areas, based on communications with my colleagues in other Regions.

The enclosed report discusses Douglas-fir beetle in relation to natural disturbances, stand risk to Douglas-fir beetles, the current status and prognosis for Douglas-fir beetle infestations, and recommendations for management of the Douglas-fir beetle outbreak on the Pine RD and Hells

Canyon NRA.

Please contact me if you have any questions about this report or Douglas-fir beetle conditions on your district.

DONALD W. SCOTT
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enclosure

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Review of 1998 Douglas-fir Beetle Infestations on the Pine Ranger District and Hells Canyon National Recreation Area

Wallowa-Whitman National Forest

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Report No. BMZ-99-1
December 1, 1998

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BMZ-99-1

Review of 1998 Douglas-fir Beetle Infestations on the Pine Ranger District and Hells Canyon National Recreation Area

Wallowa-Whitman National Forest

INTRODUCTION

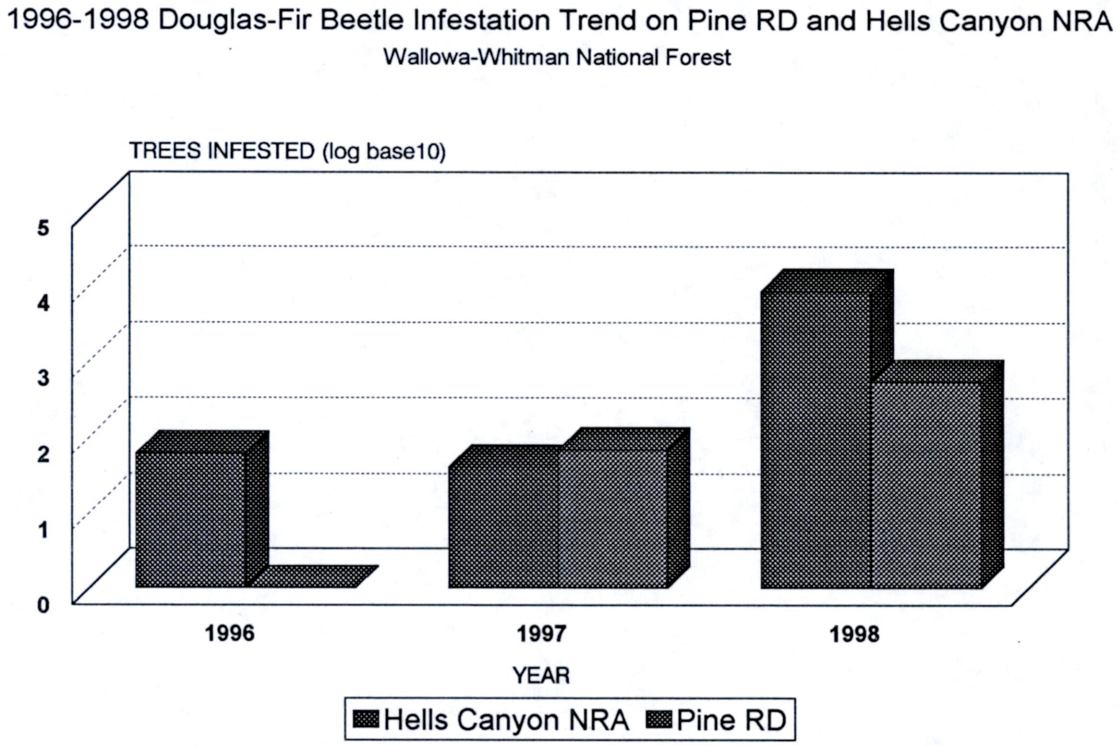
The Douglas-fir beetle, *Dendroctonus pseudotsugae*, is the most important bark beetle associated with Douglas-firs in the west. This bark beetle is a native species that prefers downed or weakened trees, but attacks and kills standing, healthy green trees in groups when population levels are high. Adult populations readily breed in the abundance of the habitat created by disturbances such as defoliator outbreaks, severe droughts, fires, windstorms, snow and ice breakage, and floods. It is under these conditions that populations often develop to an outbreak.

In the Inland West, Douglas-fir beetle outbreaks can last several years and kill thousands of the largest and oldest trees on thousands of acres, sometimes depleting this component within large, contiguous, susceptible host stands (Wright and Lejeune 1967). The high biotic potential of the Douglas-fir beetle (the capacity of an organism to reproduce and survive in its environment) provides the species with the inherent ability to rapidly increase in numbers when their food supply is abundant, resulting in outbreaks. During endemic years, beetles usually only attack weakened, dying, and recently killed Douglas-firs. However, during the release phase of an outbreak cycle, when beetle populations are increasing at an exponential rate, the high beetle numbers that are produced in broods considerably increases the probability that hosts in otherwise healthy stands will be attacked. As beetles increase populations toward some maximum rate of increase, environmental resistance functions to limit additional expansion, and gradually leads to decline in outbreaks. This is especially apparent when large host trees become limited through beetle-caused tree mortality. Severe outbreaks can significantly threaten forest health, disrupt resource management plans on affected areas, and create heavy fuel structures that increase the risk of stand-replacement fire.

The purpose of this report is to describe the biological significance and risk to stands on the Pine Ranger District and Hells Canyon National Recreation Area with regard to the Douglas-fir beetle, and provide pest management recommendations to address the potential risk of catastrophic tree mortality from insects and fire in the future.

CURRENT CONDITIONS

Populations of the Douglas-fir beetle have increased recently on the northern portions of the Wallowa-Whitman National Forest. Analysis of aerial insect detection survey data for the Pine Ranger District and Hells Canyon National Recreation Area (HCNRA) from 1996-1998 suggests a trend toward rapid population expansion, as measured by numbers of trees infested (Fig. 1). The rate of change in numbers of trees infested with Douglas-fir beetles over this three-year period is quite dramatic. Since most infested trees had not turned red at the time this insect detection survey was flown for 1998, a large number of the beetle-infested trees were actually undetected; hence, these data underestimate the actual levels of the infestation. Ground mapping of the infestations on the Pine Ranger District confirmed that significantly more trees were infested by Douglas-fir beetles than are indicated in figure 1. There may be as much as, or more than, 5-10 times the number of trees infested by Douglas-fir beetles than indicated by the aerial survey data for 1998 in figure 1.


1996-1998 Douglas-Fir Beetle Infestation Trend on Pine RD and Hells Canyon NRA

Wallowa-Whitman National Forest

Data estimated from annual aerial insect detection surveys

Figure 1. Infestation trend by Douglas-fir beetle on the Hells Canyon National Recreation Area and Pine Ranger District, Wallowa-Whitman National Forest from 1996 to 1998.

Pine Ranger District personnel identified more than 120 individual Douglas-fir beetle infestation centers ranging in size from one to more than 100 trees recently killed by beetles on the Pine Ranger District alone. These infestations occupy portions of legal sections encompassing more than 50 square miles of Douglas-fir stands in Township 6 South, Ranges 45, 46, and 47 East, and Township 7 South, Ranges 45, 46, and 47 East.

My visits to the Round Mountain area of the Pine Ranger District on July 22, 1998, and the Imnaha River drainage and vicinity on Hells Canyon National Recreation Area on July 28, 1998, confirmed high levels of Douglas-fir beetles in both administrative areas. Virtually every drainage in the area east and northeast of the Twin Lakes Fire, and south of the Imnaha River, contained previously undetected Douglas-fir beetle infestations, including the subdrainages adjacent to Forest Road 39 (Lonesome Saddle Area, Lonesome Creek, Duck Creek, the northern headwaters of Pine Creek, Dutchman Creek, and North Creek, to name a few). In addition, we observed multiple infestation centers containing many dead and dying Douglas-firs on both sides of the Imnaha River Canyon. A closer inspection of trees in several stands revealed the presence of reddish-brown boring dust in bark crevices. By removing bark from portions of the lower bole on these trees, we exposed galleries containing brood larvae beneath the bark, which confirmed the presence of Douglas-fir beetles as the causal agent of tree mortality.

The Twin Lakes Fire that occurred at the northern end of the Pine Ranger District in 1994, and spread northward a short distance into the HCNRA before containment, was initially thought to be the main source of the spreading Douglas-fir beetle infestation. Indeed, some of the recent infestations close to the fire originated in living, large-diameter, fire-scorched, unsalvaged Douglas-firs at the site of the fire, and spread from there to nearby areas. However, a broader evaluation of stands on both the Pine Ranger District and the HCNRA revealed that many new infestations were present in other drainages that were distant from the fire, and may be more directly related to, or exacerbated by disturbance processes other than the Twin Lakes Fire. These further investigations uncovered a source of a beetle habitat in windthrown trees and windstorm-broken boles that were widely scattered over large portions of both administrative units--probably all the results of the severe windstorms which occurred in December 1996/January 1997, and in April 1997. Douglas-fir beetles began attacking this blowdown debris, and after building up large populations, moved into adjacent green stands when the blowdown was no longer suitable for a habitat. Bark beetles have now begun enlarging infestation centers and spreading to other areas, as their numbers swell in an outbreak.

DISCUSSION OF FINDINGS, BIOLOGICAL SIGNIFICANCE, RISKS, AND PEST MANAGEMENT RECOMMENDATIONS

Douglas-fir is a principal component of many mid montane forests on the Pine Ranger District and Hells Canyon National Recreation Area. It occurs over a range of biophysical environments ranging from the cool-wet to the warm-dry environmental zones. It is most abundant in low to middle elevation forests where it forms climax plant communities on warmer, drier sites than true firs and moister, cooler sites than ponderosa pine (Johnson 1993). In many stands that have been unentered by harvest, or have had only light partial-cut harvest entries in the past, large-diameter, mature, or overmature Douglas-firs occur with some abundance. The prevalence of butt rot that may occur in these older trees predisposes them to windthrow, and recent windthrown trees are important breeding material for the bark beetle (Mathers 1951). After colonization of blowdown habitat created by a severe windstorm, these older trees are often the first to be attacked by Douglas-fir beetles. Populations that develop in the blowdown, leave the blowdown and begin aggressively mass-attacking live, standing trees when no other dying and weakened hosts are present in stands. Walters (1956) states that trees more than 150 years old, particularly those that are slow growing, are more susceptible to attack by Douglas-fir beetles than younger, vigorous trees; and that overmature, decadent stands often suffer considerable annual depletion. Furniss and others (1981), and Schmid and Amman (1992) state that high density Douglas-fir stands composed of 120-year-old and older large-diameter trees are highly hazardous for Douglas-fir beetle epidemics. Typically, these are trees that are at least 16-inches in diameter and larger.

The Douglas-fir beetle has two adult flights (Fig. 2). The main flight occurs in spring (mid-April thru end of June, depending upon elevation), and consists of beetles that overwintered mostly as new adults. The second, or summer flight occurs about a month later. The second flight results from a small percentage of the population (perhaps 10-20%) that overwintered as larvae and completed development in spring, and reached maturity in summer. Overwintering adults that produced the first brood in the spring may re-emerge and attack again during the summer and produce a second brood (Gast and others 1991). There is only one generation produced per year, but the beetle population can have overlapping broods. The second flight usually produces less intense attacks than the main spring flight, and is less critical with respect to a new infestation of living trees (Walters 1956). However, it may contribute significantly to ongoing infestations by drawing in considerable numbers of other beetles that are also flying during this time.

When beetle populations are low, weakened trees may be strip-attacked for two or more years before the tree is killed. Frequently in these cases, the basal portion of the tree for 15 to 30 feet is not attacked, or, if infested, may not be attacked for sometime until after the higher portions of bole have been killed (Bedard 1950).

Most outbreaks of Douglas-fir beetles have resulted from major disturbances such as windstorms or fire events. The abundant habitat created under these conditions permit beetle populations to build rapidly and spread to adjacent green, standing trees. Damage is greatest in dense stands of mature Douglas-fir (Schmitz and Gibson 1996). Douglas-fir beetles become more aggressive in attacking trees when populations are high, and easily kills healthy green trees due to sheer numbers of beetles that aggregate to trees in response to pheromones. Largest trees are preferred, and are those that most often are attacked first.

In unmanaged stands, Douglas-fir beetle attacks are most successful on trees that are mature or overmature, largest in diameter, and found in more densely stocked stands (Schmitz and Gibson 1996). As this habitat is depleted, smaller-diameter and younger, more vigorous trees are attacked. A very high stand density may increase the susceptibility of younger and smaller-diameter trees (Schmitz and Gibson 1996); although brood production in these latter trees is usually low and survival is poor. Numbers of beetles gradually wane under the influence of mortality factors in the environment, and eventually the populations collapse due to trees' natural resistance mechanisms coupled with other factors of environmental resistance (parasites and predators, and weather factors), and the depletion of suitable hosts. However, during the course of these outbreaks, thousands of trees may be killed within a given drainage, often depleting the large, mature and overmature trees, and reducing numbers of smaller trees in the stand.

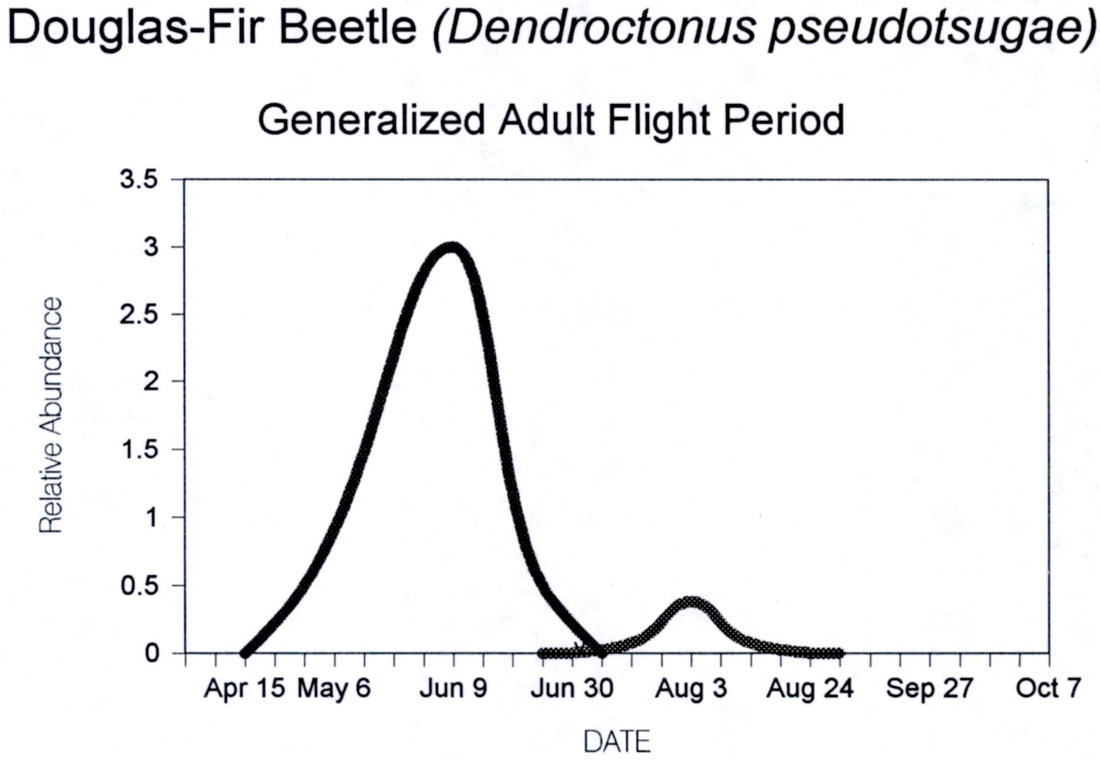


Figure 2. Generalized diagram of adult flight of the Douglas-fir beetle, *Dendroctonus pseudotsugae*, in the Blue Mountains.

Outbreaks of Douglas-fir beetles in Interior Columbia River Basin forests and the Inland West differ from those of the coastal areas of Oregon and Washington. Douglas-fir beetles in the inland regions are much more aggressive than populations west of the Cascade Mountains (Bedard 1950). Outbreaks often last many years and may not decline until essentially all the trees of susceptible size (usually over 10 inches D.B.H.) in a stand or drainage are killed (Wright and Lejeune 1967). Outbreaks in coastal areas rise and fall rapidly, usually within 2 or 3 years time (Gast and others 1991). Even so, by attacking the oldest and largest of trees in the stand they can contribute to the mortality of a substantial volume of timber in a relatively short span of time.

During our review of the Pine Ranger District and HCNRA we observed that Douglas-fir beetles had been attacking green Douglas-firs for at least the last couple of years. Beetle populations had been developing on the periphery of the Twin Lakes Fire, and in recent scattered blowdown occurring across the forested landscapes, and have now spread to other nearby locations. Attacks in fresh blowdown and standing trees now result from beetles emerging from older blowdown material or standing hosts that were attacked last year. Some beetles spreading to green timber are attacking, first, those hosts weakened by Douglas-fir dwarf mistletoe (*Arceuthobium douglasii*) or Armillaria root disease (*Armillaria ostoyae*), or those experiencing slow growth, and others having been weakened by recent defoliator outbreaks and drought during the past decade. It is significant to note that attraction of Douglas-fir beetles to these hosts will also result in some nearby healthy, standing green trees being attacked by beetles due to "spill over" effects (Johnson and Belluschi 1969). Basically, spill over occurs when more beetles are attracted to the initial "focus" tree than that tree can accommodate. The process actually involves chemical repellency signals emitted by beetles after mating, and results in incoming beetles "switching" attacks to other nearby trees. These attacks, in turn, set up an attraction process drawing in more beetles until these trees reach a saturation level or carrying capacity, too, and incoming beetles again are repelled, and forced to attack other trees. The process continues until trees have absorbed the population of beetles that were drawn to this infestation center. This process explains why Douglas-fir beetles often kill trees in groups of various size. When populations drawn to the focus tree are small, few trees are killed; when populations are large, many trees may be killed.

Biological Significance, Prognosis, and Risks:

The live, unharvested fire-injured host trees on the Twin Lakes Fire, and recent windstorms that caused the blowdown, created changes in the quantity and quality of the food supply for bark beetles. This abundant food supply encouraged endemic beetle populations to readily increase to epidemic numbers. Not only do large weakened trees, and recent windthrow provide a favorable habitat for beetles, these trees typically have little or no resistance to attacking beetles. These trees have reduced capacity to produce a flow of resin which is a critical component of resistance to insect attack (Barbosa and Wagner 1989). The flow of resin into a wound created by an attacking beetle is the first line of defense of a live tree to prevent colonization by beetles by pitching them out.

Given the diminished ability of fire-damaged and wind-damaged trees to "pitch out" beetles, Douglas-fir beetles attacking these habitats are highly successful in producing brood, and populations increase rapidly when this habitat is abundant. Survival of overwintering broods will also be high since the large trees that are preferred by the beetles contain thick bark that can protect the brood from natural enemies and adverse weather conditions. The rapid increase in beetle population allows beetles to surpass the natural regulating influence of natural enemies. However, over time, the consequential, functional and numerical responses of the natural enemy populations ultimately contribute to the waning beetle population.

If the cambium of fire- and wind-damaged trees remains alive and fresh, some beetles will continue to utilize this habitat for more than one year. As the colonizing insects deplete the available blowdown habitat they will switch to standing green trees on the site. Larger, slow growing trees, particularly those in overstocked, shaded environments containing a dominant component of Douglas-firs will continue to be attacked over the next 2 to 5 years. Gradually, smaller diameter trees down to about 8 or 10 inches d.b.h. will be attacked.

Throughout the host-type stands of the Pine Ranger District and HCNRA, windthrown Douglas-firs, and broken Douglas-fir boles have resulted in attraction of beetles, and placed nearby standing trees at risk of attack. Once in the immediate area of this blowdown, bark beetles indiscriminately attack not only the blowdown timber that attracted them, but nearby standing trees as well (Johnson and Belluschi 1969; Johnson and Pettinger 1961). Studies by Johnson and Pettinger (1961) showed that if the beetle populations are low and the amount of windthrow is high, little tree mortality will occur from infestations the year of the windstorm. However, when the beetles are abundant in relation to the amount of windthrow, scattered tree mortality will occur as the beetles aggregate numbers to the windthrow and begin attacking neighboring trees (Johnson and Belluschi 1969). Aerial and ground surveys conducted over the past several months by personnel of the Pine Ranger District have provided a good estimate of numbers and distribution of infestation centers in stands at the current time. This type of data is currently only available for a small portion of the HCNRA, but the 1998 aerial insect detection survey has identified many of the centers of beetle infestation in other parts of the district, that were visible at the time of the flight (i.e., July).

There is continued high probability that some beetles will spread into adjacent new stands containing a susceptible component of Douglas-fir, next year. This probability is based on the fact that an insect and disease risk analysis of the Pine Creek Watershed in 1997 found that nearly 40 percent (36,362 acres) of the 95,587 acres analyzed were identified as being at "high" risk to Douglas-fir beetles (Schmitt and Scott 1997). The adjacent watershed to the west (Eagle Creek), where Douglas-fir beetles have been active for several years, was also similarly analyzed for insect and disease risks in 1996 (see Schmitt and Scott 1996). Insect and disease risk analysis for the Eagle Creek Watershed found that over 25 percent (22,641 acres) of the 89,491 acres analyzed in the watershed were identified as "high" risk to Douglas-fir beetles. A similar insect and disease risk analysis was conducted on the entire Hells Canyon National Recreation Area (Scott and others 1995). This analysis identified 19 percent (91,824 acres) of the 482,550 acres analyzed as being "high" risk to Douglas-fir beetles. In total, this represents a significant number of acres of mature and overmature stands in the eastern portion of the Wallowa Mountains, as shown in figure 3.

With continuing beetle population increase and spread over the next 2-5 years, these data indicate a high risk of Douglas-fir beetles killing some portion of the Douglas-fir in stands on well over 150,000 acres on this portion of the Wallowa-Whitman National Forest. The actual tree losses within individual stands cannot be easily estimated beforehand; but, we have studies from one such high-risk stand on the Umatilla National Forest in which Douglas-fir beetles had killed 89% of the Douglas-fir basal area (representing 63% of the Douglas-fir stocking in trees per acre), over about 3 or 4 year's time. This stand had exceeded the recommended Upper Management Zone Stand Density Index (SDI) for managing Douglas-fir, as given by Cochran and others

(1994).

In the current outbreak, the majority of beetles will likely spread only short distances to adjacent stands, or expand existing centers outward if both local beetle populations and susceptibility of host stands are high. Although the Douglas-fir beetle is capable of sustained flights of 20 to 30 miles, it is believed that they usually do not fly more than a mile or so when there is preferred host material within that radius (Lejeune and others 1961). However, even in the normal dispersal pattern there will likely be some long-distance dispersal of beetles in every flight of beetles. The older trees of large diameter and slow growth are at greatest risk of attack by Douglas-fir beetles

1998 DOUGLAS-FIR BEETLE RISKS ON HELLS CANYON NATIONAL RECREATION AREA AND PINE RANGER DISTRICT

(Weatherby and Thier 1993 DFB Risk Model)

RISK CATEGORY	ACRES	PERCENT OF AREA
Unknown	6,406	1.0
Low	495,965	74.1
Moderate	16,125	2.4
High	150,727	22.5
TOTALS	669,223	100.1

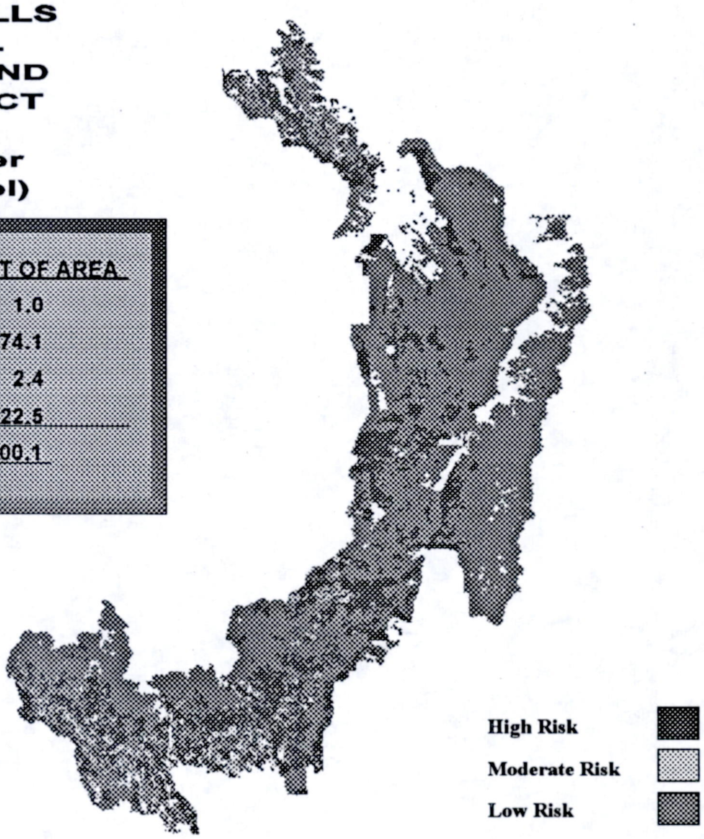


Figure 3. Relative risk of stands to attack by Douglas-fir beetle, *Dendroctonus pseudotsugae,* on Hells Canyon National Recreation Area and Pine Ranger District, Wallowa-Whitman National Forest.

because they often have a slower growth rate than the average for the stand, and are frequently injured by fire, storms, landslides, and other such disturbances that make them susceptible to beetles (Hopkins 1909; Mathers 1951). Spot infestations in those stands will result in the killing of small groups of trees. These spots may become sources for other infestations in nearby stands, and help spread the outbreak, or these infestation centers, themselves, may be expanded as beetles continue to increase in numbers and kill more trees within, or in close proximity to the infestation in subsequent years. Some spots may coalesce with others nearby to form larger areas of beetle-caused tree mortality. If stand and weather conditions are favorable, it is anticipated that beetles will be successful in killing standing green trees for 2-5 more years in stands with slow-growing mature or overmature host trees, as well as some healthy, younger trees. Beetle populations should decline after that. These epidemics usually decline due to the combination of depletion of large host trees, beetle attacks on resistant and smaller-diameter vigorous trees, from pressure from natural enemies that have increased in response to their increased prey base, and from weather-related and other mortality factors.

Beetle populations often build to outbreak levels when habitat created by natural disturbances is not removed in a timely manner. When this happens, the outbreak is more difficult to manage than while populations are still at the earliest stages of the increase. Once populations are increasing unimpeded they can potentially move throughout drainages containing slow-growing, large-diameter host trees, mass-attacking and killing both weakened and healthy trees, and virtually eliminate the large-tree Douglas-fir component in those stands. Moreover, from an area-wide perspective, some unknown proportion of the beetle population may disperse further than the immediate stand or drainage, and focus or extend the outbreak into distant, new areas. These scenarios describe situations similar to the old-growth and riparian area tree losses that occurred during the recent western spruce budworm (*Choristoneura occidentalis*) outbreak a few years ago when Douglas-fir beetles built-up in response to weakening of trees by defoliation and drought. Depending on the proportion of the stand that is in Douglas-fir, any amount of the stand containing trees over 8 or 10 inches d.b.h. could be lost to Douglas-fir beetles, up to the entire stand.

There is an even greater sense of concern and urgency about these increasing Douglas-fir beetle populations when one considers the evidence that shows that Douglas-fir tussock moth (*Orgyia pseudotsugata*) populations on the Pine Ranger District and HCNRA are also on the increase; and, indeed, the West may be presently moving into another Douglas-fir tussock moth outbreak cycle (unpublished 1998 trapping data and lower crown sampling data; ref. 3410 letter dated February 26, 1998, and 3420 letter dated July 13, 1998). Outbreaks of tussock moth characteristically weaken and kill many Douglas-firs and grand firs over thousands of acres of susceptible forest land within a 3- or 4-year period, before the populations decline. Douglas-firs that are left in weakened condition after a tussock moth or western spruce budworm outbreak are often attacked and killed by Douglas-fir beetles (Fredericks and Jenkins 1988; Hadley and Veblen 1993; Wright and others 1984). A pre-existing high population of Douglas-fir beetles could spell serious trouble for the mature and overmature Douglas-firs in stands affected by both tussock moth and Douglas-fir beetles. The combined effects of these insects could potentially leave a considerable volume of timber standing dead in the forest in the years to come.

The standing dead trees will contribute to a component of large, dead, ladder fuels that will place these stands at increased risk to catastrophic stand-replacing fire in the future. The relative risk will be in proportion to the amount of stand killed by beetles. Eventually, when the dead trees fall, while they may contribute to habitat for various animals as a down-woody component, they may also impede the movement of animals and humans alike, and will provide a considerable fuel bed for other future potentially catastrophic fire events.

Recommendations:

The following general recommendations for managing Douglas-fir beetle infestations in stands of the Pine RD and HCNRA provide an Integrated Pest Management (IPM) approach that simultaneously utilizes several techniques to modify or reduce the habitat for the beetle and manipulate beetle populations to lessen the probability of continuing to build outbreaks. Any individual technique can be used alone as a treatment alternative, but combining the techniques in an integrated approach greatly improves chances of successful management of beetle populations.

Starting early is the key to success in controlling Douglas-fir beetle infestations. If undertaken during the 1-year interval between initial beetle attack and emergence, the infestation will be more easily managed than later on when beetle populations have increased significantly, and have begun to spread to new hosts and other areas.

Sanitation/Salvage

The management of the Douglas-fir beetle situation, whether in trees injured by fire or in blowdown, must begin with the removal of the susceptible, uninfested windthrown or fire-injured trees, and the currently infested host material that were windthrown or damaged by the fire (but not infested until recently). If done promptly, this can be the most effective treatment method for aggressively managing bark beetles. Prompt salvage of fire-injured and windthrown trees or currently infested trees can forestall epidemics (Gast and others 1994; Schmitz and Gibson 1996). The removal of breeding habitat for beetles is paramount to avoiding a buildup of bark beetles on the site and spread to other locations. Since the beetle prefers breeding in large-diameter hosts (Hadley and Veblen 1993), it is particularly important that those hosts be removed, either before they become infested, or if infested, before the beetles complete development and emerge one year later (next spring). Large-diameter host material contains a large amount of inner bark surface area, and can produce large numbers of beetles. The beetles prefer down trees, and although they may produce less dense galleries than in standing trees, the relative survival of beetles in down trees is likely to be greater (Furniss 1959).

As a first priority in a strategy to avoid continued buildup of bark beetles, immediate attention should be given to removing any currently infested concentrations of large-diameter host material from sites for mill processing prior to adult beetle emergence. This action also implies a lower diameter limit to remove. Lejeune and others (1961) found that the greatest numbers of beetles are produced in logs over eight inches in diameter and in stumps. While it may not be possible to identify and remove all currently-infested windthrown trees and broken pieces of bole-size larger than eight inches, it is probably most important to remove as much of the largest infested material as possible from the shaded habitats, and dispose of the remaining susceptible pieces by jack-piling and burning, burning in place, or other suitable methods. Since the beetle favors the larger pieces, it is especially critical to remove the largest diameter host material first because beetles can potentially produce the largest broods in these hosts. Also, if fresh, wind-damaged host material must be left, it should be the smaller diameter pieces.

Felled Trap Trees

In 1991, the Wallowa Valley Ranger District sought advice in managing a Douglas-fir beetle infestation that developed after a series of wildfires on the district promoted the buildup of bark beetles. Infestations spread from the fire area to old-growth and riparian stands on the district in subsequent years. The District undertook an aggressive salvage and sanitation operation during 1991-1992 to remove beetle-killed trees, including those still containing broods. It was not possible to remove all the currently-infested trees, so other options were needed in addition, to help manage the outbreak.

The bark beetle outbreak afforded the opportunity to test a combination of antiaggregation and aggregation pheromones to protect high-risk Douglas-fir stands from Douglas-fir beetles. While this work was being cooperatively undertaken by Oregon State University and the U. S. Forest Service (Pacific Northwest Research Station; see Ross and Daterman 1994), One of us (Scott) provided some interim guidelines for trap trees. Trap trees when used early in an outbreak sequence can reduce beetle-caused mortality in standing trees (Schmitz and Gibson 1996). The following were based on guidelines in the 3460 file letter of August 21, 1991 to the Wallowa Valley Ranger District. The present guidelines are modified somewhat from the original.

The trap tree guidelines form the next part of the IPM strategy for managing Douglas-fir beetle populations. The original guidelines were developed for standing green-infested trees. They assumed that current beetle-infested trees in each infestation locus numbered less than about 20, and these trees were spread over an area of approximately 7-10 acres or less. Usually there are several such groups of infested trees within a riparian drainage. The actual distribution and density of beetle-infested host material on the Pine Ranger District and HCNRA may vary somewhat from the above conditions. Since it is difficult to determine the actual locations of all beetle-infested hosts without a 100-percent survey, which is impossible for the size of the land area involved, we have modified the original guidelines for more generalized application, as originally given by Lejeune and others (1961). In practice, trap trees would probably only be used in certain areas dictated by accessibility, size of infestation, abundance and size of host trees, relative distance from high-value stands requiring protection, and other factors. These numbers and distribution of trap trees can be determined later in consultation with the districts.

(1) During winter, or just prior to spring beetle flight (preferably not later than the first week of April), fell groups of green, large-diameter Douglas-firs (preferably 16-inches or larger, but not less than 10-inches d.b.h.) in groups of about 10 trees per group, as

trap trees. The groups should be placed in locations that will facilitate easy removal (i.e., adjacent to open roads). The affected area should be gridded with groups of trap trees at about ¼ to ½ mile intervals.

Trap trees should be felled into the deep shade near other infested trees or boles, or close to infested trees whenever possible. This will help contain the infestation to the several created infestation loci. Trap trees should be left unbucked and unlimbed. Allow branches on the underside to support the bole up off the ground so that direct contact with the ground is avoided or minimized. Beetles will be attracted to these trap trees and will set up a strong secondary attraction, drawing in other beetles, and possibly leading to other nearby standing trees being attacked. There is a strong likelihood that other green-standing trees near the trap-tree locations will be attacked by beetles as they are drawn into the trap trees and make random attacks on standing trees, or "switch" from attacks on downed trap trees to standing trees in response to odor plumes emanating from hosts under attack by beetles. Each infested host may have an attraction influence that leads to attack on other host trees within a radius of 33-35 feet, due to the presence of beetle-produced aggregation pheromones (Johnson and Belluschi 1969; Knopf and Pitman 1972).

(2) Trap trees should remain in place in the woods, at least through August, to allow adequate time to absorb the flying adult population. Remove all the infested material (including standing green-infested trees) from the area, preferably by fall, and certainly before the brood completes development and adults emerge the following spring (i.e., remove before April the following year). **Important: it is critical that these infested trap trees be removed in a timely manner to prevent further buildup of beetle populations. If the removal or destruction of infested trap trees cannot be assured by April of the following year, this method should not be used!** To insure the removal of infested trap trees, special contract clauses could be used to require appropriate and timely removal of the infested material by the purchaser.

Do not use trap trees in a riparian drainage and in high-value stands that do not already contain infested blowdown or current active beetle populations. To do so is inviting beetles into a new area, with the possibility of starting new, unwanted infestations.

Baited Trap Trees

This technique is a modification of the Trap Tree procedure that uses commercially available tree baits containing Douglas-fir beetle aggregation pheromones to make trap-trees more competitive with natural sources of attraction, and concentrate populations at trap-tree locations (Ross and Daterman 1997a). Baited Trap Trees can be used in conjunction with the Felled Trap Tree procedure in the Integrated Pest Management Strategy, or as a substitute for the Felled Trap Tree Procedure. **Either procedure requires sacrificing a number of trees to create trap trees and absorb spillover; under both methods, trees also have to be removed after being infested,**

before the new broods of beetles fly the following spring. Baited Trap Trees have been operationally demonstrated as an effective technique in managing Douglas-fir beetle infestations as part of an Integrated Pest Management approach to a Douglas-fir beetle epidemic on the Cascade Ranger District, Boise National Forest, in west-central Idaho in 1990 and 1991 (Patterson 1992). Baited Trap Trees can also be used in a post-salvage "mop-up" of residual beetle populations.

For large areas like the stands on the Pine Ranger District and HCNRA that have populations of beetles present and increasing, the management strategy should be to try to contain current infestations within the boundary of the blowdown or concentration of beetles in standing trees. Used in conjunction with the grid of Felled Trap Trees, a "barrier" of Baited Trap Trees can be established around the perimeter of the blowdown boundary, or a grid of Baited Trap Trees could be established across the blowdown area or area of concentrated, infested standing trees, in lieu of the Felled Trap Trees procedure, in the following manner.

(1) In early spring, at least 2-3 weeks prior to anticipated beetle flight (for higher elevations in the Blue Mountains this is probably around the first or second week of April), locate and bait susceptible Douglas-firs (susceptible trees are mature or overmature live Douglas-firs preferably 16-inches or larger in d.b.h.), in a 2½- x 2½-chain grid over the area of blowdown, at the rate of 2 tree baits per acre (Thier and Weatherby 1991). It is only necessary to grid areas that have susceptible host type and contain wind-damaged or standing, green-infested hosts. Each tree bait should be stapled on the north side of individual host trees at about 8 feet from the ground. Select host trees to bait that are situated in elevated, but not overly exposed locations (i.e., avoid gullies and draws).

(2) After infestation, fell Baited Trap Trees and other infested trees nearby, and remove them to the mill for processing preferably in the fall (same as in 2 above), but no later than April of the following year. The harvest of these trees after they become infested is essential to destroy the developing brood. As with the Felled Trap Tree procedure, if infested tree removal cannot be guaranteed, this technique should not be used.

Mass Trapping (Suppression Trapping)

A procedure of trapping beetles in a special designed lethal trap (Lindgren Funnel Trap), using bark beetle lures, has been investigated as one component of an integrated system for managing the Douglas-fir beetle (Ross and Daterman 1997b). The procedure is considered a suppression tactic because the purpose is to reduce local beetle populations by mass trapping beetles (Ross and Daterman 1994). This system has some advantages over the Felled Trap Tree and Baited Trap Tree methods for managing bark beetles. The advantages include greater flexibility in trap placement, traps remain attractive throughout the beetle flight period, traps have an unlimited capacity to collect beetles provided they are maintained regularly, trees are not sacrificed *a priori*, tree harvesting may be unnecessary, impact on natural enemies can be regulated, and reemergence of parent adults does not occur (Ross and Daterman 1997b). In our IPM strategy for managing

Douglas-fir beetle infestations on the Pine Ranger District and HCNRA, we have included this component as an integral part of the strategy; however, where it might be less desirable to sacrifice more large trees to create trap trees in the area of the blowdown, this method could be employed independent of the trap tree methods. This procedure is especially appropriate where vehicle access is limited, and where there is low risk in infesting host trees by beetles as they are attracted to baited traps. However, it is important to note that where susceptible hosts are present nearby, use of this method will almost certainly result in some, or all of the nearby host trees to be attacked. Once nearby trees are attacked, these attractive sources may result in decreased trap efficiency of Lindgren Funnel Traps because the synthetic lures will probably not perform as well as the natural attractive sources nearby. **It is especially important to remove these infested trees, otherwise they will only serve to continue, and to increase the severity of the bark beetle infestation in stands.**

(1) The trapping system consists of 12- or 16-unit Lindgren Funnel Trap, and a 3-component Douglas-fir beetle lure (the 12-unit Lindgren Funnel Trap is also recommended for use in Spruce Beetle trapping programs). To provide a lethal environment for insects that drop into the collection cup, a 6-9 cm^2 piece of DDVP-impregnated plastic can be placed in the cup for "dry trapping" applications (Ross and Daterman 1997b), or alternatively, soapy water may be used for "wet trapping" applications. Select locations for traps and place traps in the field sites prior to the beginning of adult beetle flight in the spring (no later than the end of April).

The traps should be placed in groups of 2-3 traps, spaced 10 m or less apart, in the vicinity of--but not close to--the infested trees or other sources of competing pheromones (e.g., Baited Trap Trees, Felled Trap Trees), or fresh windthrown hosts. To minimize unwanted tree mortality from beetles drawn to the attractant source, it would be best to locate these groups of traps in large non-stocked openings, or in non-host stands. They should be as far away as possible from host trees that need to be protected since some host trees near the traps will inevitably become infested as beetles are attracted to the baited traps. For this reason, and because Douglas-fir beetles appear to be willing to fly into openings, the placement of the Douglas-fir beetle traps in openings or non-host stands should help reduce chances of unwanted attacks on desirable host trees (personnel communication with Dr. Darrell Ross, Oregon State University).

(2) Traps should be checked and emptied at least weekly during the peak of Douglas-fir beetle flight, and no less frequently than every other week during the rest of the season. Since beetle counts and species identifications will need to be done as part of effectiveness monitoring, it is important that beetle collections be preserved in individual containers and the containers appropriately labeled. After any period of rain, it is especially important to service the traps, as the collection cups will quickly fill with water and spill out the contents, which will be lost on the ground.

(3) Traps should remain in place through September. The trap lures are formulated in a

releaser designed to provide continuous attraction for several months, so there should be no need to change lures during the season.

(4) Remove any beetle infested trees near the groups of traps to destroy developing broods soon after traps are removed. It is important to remove these trees to avoid leaving a continuing source of beetles near susceptible stands. The IPM plan should be developed with the proviso to promptly remove any beetle-infested trees at the time traps are removed, to provide a safeguard against continuing the beetle infestation.

Antiaggregation Pheromone Baiting

This is the final component of the Integrated Pest Management Strategy for Douglas-fir beetle infestations on the Pine Ranger District and HCNRA. While the Aggregation Pheromone used in Lindgren Funnel Traps **"pulls"** Douglas-fir beetles out of the stands and concentrates them at the funnel traps, the Antiaggregation Pheromone Tree Baits or Bubble Caps, when used in specially designated stands, **"pushes"** beetles out of those stands and helps to protect trees from being attacked by beetles.

The feasibility of protecting live trees in small, high-value stands has been demonstrated in research projects in northeastern Oregon (Ross and Daterman 1994). Also, the La Grande Ranger District, Wallowa-Whitman NF, has demonstrated operational use of the antiaggregation pheromone of the Douglas-fir beetle, 3-methylcyclohex-2-en-1-one (MCH), to protect high-value, high-risk Douglas-firs at the Oregon Trail Interpretive Park in a recent pilot test (Scott, unpublished data). The use of MCH in nearby old-growth and riparian stands containing a large-diameter Douglas-fir component, while applying mass-trapping or trap trees in other areas to contain beetles and draw them to those areas, can be an effective means of protecting the Douglas-fir resource in those stands that need to be protected because of old-growth value or critical habitat for Sensitive, Threatened, and Endangered Species, and other high-value administrative areas like campgrounds.

While this technology has been proven effective in reducing or eliminating Douglas-fir beetle attacks in high-value stands, lack of U. S. registration by the U. S. Environmental Protection Agency is the main impediment to full implementation of the technology (Ross and Daterman 1997a). At the present time an Experimental Use Permit (EUP) covers field uses to evaluate MCH. The use of MCH under this EUP is governed by limitations of quantity used and size of area it may be used on annually. In Oregon, up to 750 total acres may be treated annually with MCH. Each use of MCH is approved by the Oregon Department of Agriculture Pesticide Division.

The use of MCH is included in the IPM strategy for managing Douglas-fir beetles because it affords the opportunity to pilot test the technology on an operational basis to protect specific high-value stands in a blowdown situation. We will need to provide additional consultation to the Pine RD and HCNRA if MCH is to be used in this context.

(1) Prior to any proposed treatments with MCH, the Region must secure approval from the Oregon Department of Agriculture for the number of acres and dosages used on the proposed treatment. A study plan will need to be prepared to document the proposed study objectives, evaluation procedures, etc.

(2) At the end of March or beginning of April (or a week or two later at high elevations), select specific high-value, high-risk stands to protect from Douglas-fir beetle and establish a grid of MCH bubble capsules in those stands. MCH bubble caps should be stapled to the north side of host trees (Douglas-firs), at about head-height or higher, and spaced about 5 m apart along parallel lines separated by about 20 m between lines so that an application rate of 40 caps per acre (total of 16 g a.i. per acre) is achieved over the treated area.

(3) Evaluate effectiveness of treatment at end of season by conducting a 100-percent survey of MCH-treated stands to identify total numbers of successfully attacked trees in stands, and document results in a written report.

Effectiveness Monitoring

The results of actions taken to mitigate and manage the Douglas-fir beetle outbreaks on the Pine RD and HCNRA need to be evaluated or measured to determine the degree of success in limiting additional beetle-caused tree mortality to levels that are within acceptable limits to the districts. There are a number of elements in the management of Douglas-fir beetles by the methods outlined, that is of research interest. There are presently opportunities to collaborate with research in developing a monitoring plan that may help satisfy the needs of both Forest Service Research and National Forest System Effectiveness Monitoring. Discussions on monitoring needs have started, and should be encouraged and continued, between the Pacific Northwest Research Station, Forestry and Range Sciences Laboratory at La Grande and the Wallowa-Whitman National Forest. This monitoring should be an integral part of the Integrated Pest Management program for Douglas-fir beetles as it will serve to measure treatment effectiveness, as well as help address questions on application of treatment strategies under differing resource management regimes.

FINAL COMMENTS

Wildfires and windstorms are natural disturbance events that are commonplace in the forests of northeastern Oregon and southeastern Washington. Bark beetle epidemics often follow major disturbance patterns due to the rapid and successful colonization of the abundant habitat created by the disturbances. Dead trees resulting from a bark beetle outbreak, along with debris created by the windstorm, add a significant fuel component to the landscape. Accordingly, windstorms, insect outbreaks, and wildland fire are oftentimes interconnected. One event may lead to the others as successional disturbance events play out over time. However, our concern on the Pine

RD and HCNRA is not so much that insects will follow a natural course, develop an outbreak, and kill many more trees; that they are programmed to do. But rather, our concern relates more to our obligation to the public to best manage the resources to protect, restore, and enhance critical threatened and endangered species habitats, preserve valuable scenic viewsheds and recreation areas, promote healthy sustainable forests, and protect the public by ensuring the safety of humans and their structures from other natural disturbance events that may affect them directly, such as wildfire. Forests of northeastern Oregon continue to be at risk to bark beetles, defoliators, disease agents, and wildfire. Silvicultural treatments to reduce stocking and lower fuel components should always be at the forefront of restoring overstocked, unhealthy forests to healthy condition that will enable them to better resist insects, diseases, and fire, or at least allow these disturbance agents to act in a manner more consistent with natural historic regimes. Though there is a lack of discussion of applying silvicultural methods that include harvest, thinning, use of prescribed fire, and other technology in this report, these actions should be a part of the integrated resource management plan, and go hand-in-hand with other specific pest management actions recommended in this report.

That catastrophic fires often follow a serious insect outbreak, like the spruce beetle-killed Engelmann spruce on the northern end of the Wallowa-Whitman National Forest, or the mountain pine beetle on the northeastern part the Malheur National Forest, are evidenced by such major fires as Canal, Twin Lakes, Sheep and Snowshoe, and others. Insect outbreaks can seriously damage forest resources by rapidly depleting a large volume of valuable trees, but fires that often follow insect outbreaks through the ignition and combustion of the significant levels of dead fuels created by insects, are far more destructive to the entire landscape and the resources contained therein.

We believe that application of the IPM plan described in this report, while not being perfect, has the best chance of limiting the amount of additional losses of trees by insects, and damage to stands and resources, if begun early and undertaken aggressively. Without these actions, there will be continued serious losses from Douglas-fir beetles in susceptible host stands; very likely leading to some order of stand-replacing fire event in these insect-damaged stands in the future.

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